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Roni Avissar

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14. ABSTRACT
The main objective of the Canopy Horizontal Array Turbulence Studies (CHATS) was to provide the relevant data needed to improve the parameterization of sub-filter-scale (SFS) processes in the roughness sub-layer that is affected by canopy-atmosphere interactions. For that purpose, NCAR deployed in March-June 2007 an array of sonic anemometers at different heights and lateral separations in a homogeneous walnut orchard in the Central Valley of California so as to capture the influence of the wake-scale motions in the lee of vegetation. Together with this array, other instruments (including a high tower and a new eye-safe lidar) were operating during the field campaign. While this equipment provided an excellent dataset

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Report Title

Measurement of ABL Turbulent Fluxes with the Duke University HOP

ABSTRACT

The main objective of the Canopy Horizontal Array Turbulence Studies (CHATS) was to provide the relevant data needed to improve the parameterization of sub-filter-scale (SFS) processes in the roughness sub-layer that is affected by canopy-atmosphere interactions. For that purpose, NCAR deployed in March-June 2007 an array of sonic anemometers at different heights and lateral separations in a homogeneous walnut orchard in the Central Valley of California so as to capture the influence of the wake-scale motions in the lee of vegetation. Together with this array, other instruments (including a high tower and a new eye-safe lidar) were operating during the field campaign. While this equipment provided an excellent dataset at the tree-to-orchard scale, this experiment needed a general characterization of the entire ABL so that a full picture of the dynamics involved in the land-atmosphere interactions taking place above the orchard could be assessed. This missing link was provided by the Duke University Helicopter Observation Platform (HOP), which flew about 35 hours in 7 days distributed over the period April-June 2007. For each day, two, 2.5-hour flights were performed (mid morning and early afternoon). During these flights, the Duke HOP measured 3D turbulence, temperature, moisture, and CO2 in five transects at several heights from tree top to the top of the atmospheric boundary layer.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

see manuscripts - 1 paper submitted and 2 in preparation

Number of Papers published in peer-reviewed journals: 0.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Number of Papers published in non peer-reviewed journals: 0.00

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

(d) Manuscripts

Avissar, R., H. E. Holder, P. Canning, K. Prince, N. Matayoshi, R. L. Walko, and K. M. Johnson, 2008. The Duke University Helicopter Observation Platform. Bulletin of the American Meteorological Society (submitted).

Holder, H.E. and R. Avissar, 2008. Measurements of turbulent fluxes in the atmospheric boundary layer with the Duke University Helicopter Observation Platform. J. Atmos. Ocean. Tech., to be submitted by 04/01/2008.

Holder, H.E., K. Novick, D. Lenschow, N. Patton, W. Eichinger, N. Matayoshi and R. Avissar, 2008. An evaluation study of the turbulent fluxes measured on board the Duke University Helicopter Observation Platform. J. Atmos. Ocean. Tech., to be submitted by 04/01/2008.

Number of Manuscripts: 3.00

Number of Inventions:

Graduate Students

NAME	PERCENT_SUPPORTED
Heidi E Holder	0.00
Adam M. Bolch	0.00
FTE Equivalent:	**0.00**
Total Number:	**2**

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Roni Avissar	0.00	No
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
Patrick Canning	0.00
FTE Equivalent:	**0.00**
Total Number:	**1**

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

FINAL REPORT

Project ID:	52861EVII
Title:	*Measurement of Atmospheric Boundary Layer Turbulent Fluxes with the Duke University Helicopter Observation Platform (HOP) in support of CHATS*
PI:	Roni Avissar
Institution:	Duke University – Civil and Environmental Engineering
Period:	April 2007 to January 2008
Cost:	$50,000

Justification

To improve our understanding of the mechanisms and processes involved in the diffusion of passive tracers and to improve our capability to simulate them, we need very-high resolution (spatial and temporal) observations of turbulence and scalars in the entire atmospheric boundary layer. Due to technological complexity and cost, so far, no such dataset has been produced. The Canopy Horizontal Array Turbulence Studies (CHATS) carried out by the National Center for Atmospheric Research (NCAR) in March-June 2007 together with the observations collected with the Duke University Helicopter Observation Platform (HOP) offered, for the first time, the unique opportunity to produce such a dataset.

Introduction

The motivation for CHATS was provided in the Experimental Plan written by Lenschow et al. It also provides the relevant literature review necessary to understand the background for CHATS and, finally, it describes some of the instruments deployed for the field campaign. Thus, for brevity, this material is not repeated here (a copy of it can be found in our proposal). Here, we just provide a list of the flights conducted during CHATS and we describe the research being performed with the data that were collected.

The Duke Helicopter Observation Platform (HOP)

The Duke University's Helicopter Observation Platform (HOP) is now described in detail on a dedicated website at http://hop.pratt.duke.edu. For instance, the various characteristics of the sensors currently mounted on it (which are illustrated in Figure 1), are provided there. Interested readers are referred to that electronic document. These sensors were operational during the CHATS field campaign and, therefore, we measured 3D wind components at 40 Hz with two different technologies, one based on pressure sensors (with the Aventech AIMMS-20) and one based on ultrasound (with the Kaijo-JAXA USV). These sensors also provide temperature measurement at the same frequency. We also measured water and CO_2 content at 120 Hz (smoothed to 40 Hz) with the Licor 7500. Thus, using the eddy-correlation technique, we can use these observations to calculate momentum, heat (sensible and latent), and CO_2 turbulent fluxes. The procedure to denoise and detrend the data collected on-board the HOP is explained in Holder and Avissar (2008)[1].

HOP Participation in CHATS

The main objective of CHATS was to provide the relevant data needed to improve the parameterization of sub-filter-scale (SFS) processes in the roughness sub-layer that is affected by canopy-atmosphere interactions. For that purpose, NCAR-ESSL/EOL deployed an array of sonic

[1] As we used the CHATS data to improve our detrending technique and validate the performance of the HOP (see Holder et al. 2008), relevant publications (i.e., Avissar et al 2008, Holder and Avissar 2008, and Holder et al 2008) acknowledge the contribution of ARO, even though this was not part of our original project.

anemometers at different heights, height separations, and lateral separations so as to capture the influence of the wake-scale motions in the lee of vegetation. A homogeneous walnut orchard in the Central Valley of California was used for this field campaign (Figure 2). This is an ideal location because of the consistent and predictable wind direction and the vast, homogeneous orchards in flat terrain, which are found there. The array was deployed normal to the predominant wind direction within an orchard row with some separation between plant elements and the sonic anemometers and with ample upwind fetch[2]. It should be mentioned that such an experiment had not been previously attempted, mostly because of the technological challenges. Together with the above-mentioned array, other instruments (including a high tower and a new eye-safe lidar) were deployed.

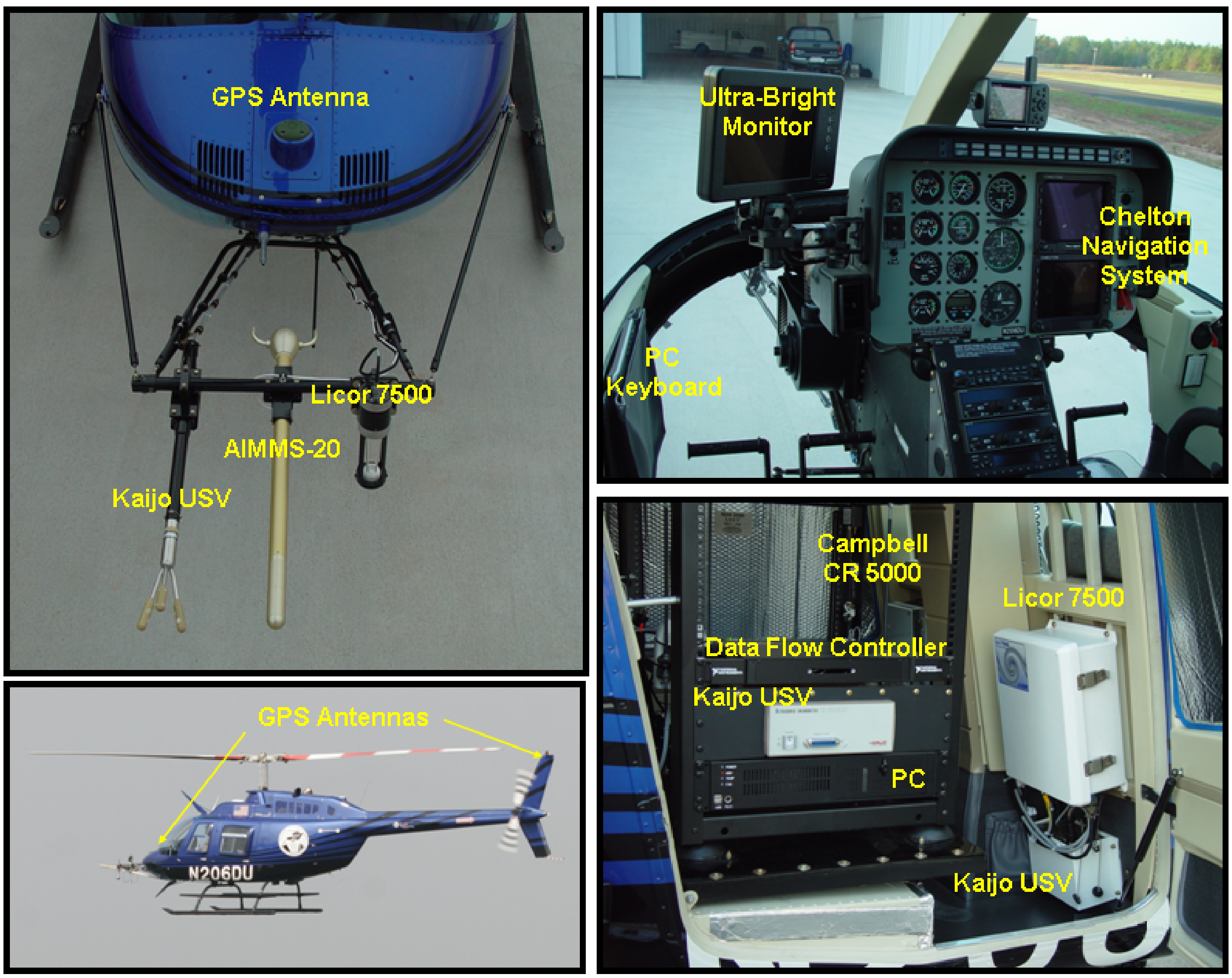

Figure 1: *The Duke HOP basic sensors [including a Licor 7500 (www.licor.com), an Aventech AIMMS-20 (www.aventech.com), and a Kaijo Corporation Ultrasonic Velocimeter (USV)] mounted on its nose, positioning system (including differential GPS and a 3D accelerometer system inserted inside the AIMMS-20), data acquisition system (including a Campbell Scientific data logger (www.campbellsci.com), a data flow controller and a PC mounted in the back cabin) and real-time visualization system in the front cabin. The USV is a prototype developed by Kaijo in collaboration with Japan Aerospace Exploration Agency (JAXA).*

[2] Other details regarding CHATS can be obtained at http://www.eol.ucar.edu/rtf/projects/CHATS/isff/report.shtml.

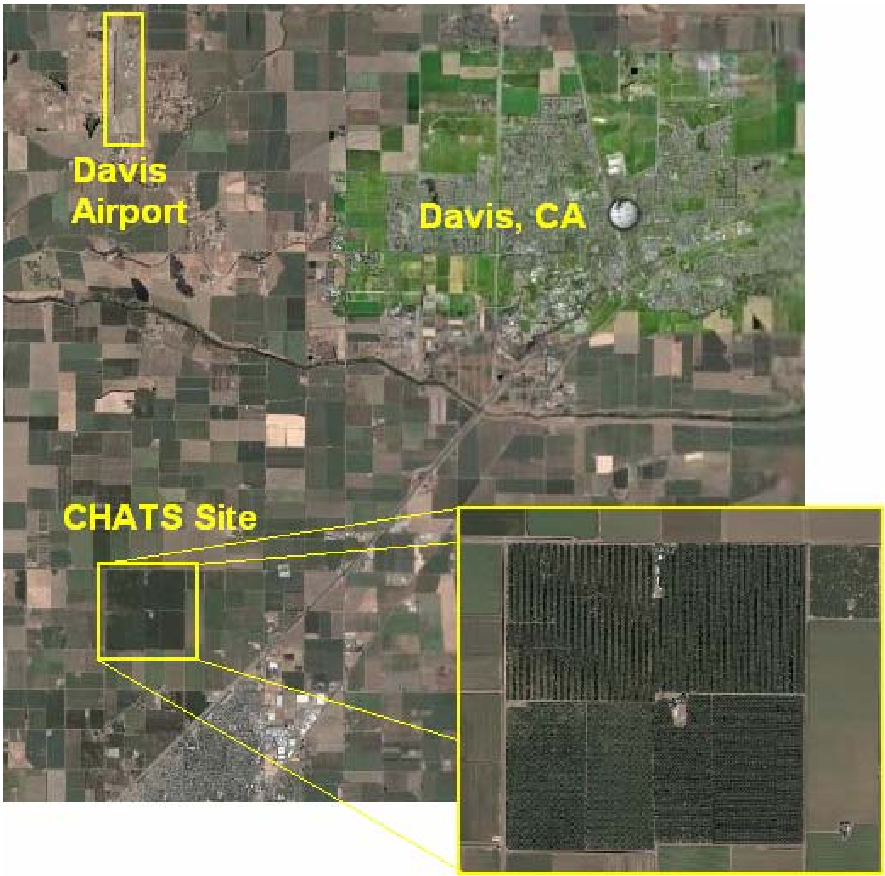

Figure 2: *Satellite view of the CHATS experiment site. The image on the left shows that the orchard is located 5 miles south-west of Davis, CA, and 6 miles south of Davis Airport, where the HOP was refueling. The image on the right is an enlargement of the orchard (shown by the yellow square in the left-side image) where the equipment was deployed and where the HOP flights were conducted. Both images are oriented North, and wind direction at the site is typically either from the South and occasionally from the North.*

While the equipment that was deployed by NCAR was expected to provide an excellent dataset at the tree scale (and orchard scale with the lidar), the experiment needed a general characterization of the entire boundary layer so that a full picture of the dynamics involved in the land-atmosphere interactions taking place during the field campaign could be assessed. This was achieved by performing repeated flight legs at different altitudes and time of the day. Figure 3 provides a diagram of the flight legs that were performed on one of the experimental days.

We flew these legs on six different days: April 10, May 14, May 15, May 23, May 25 and June 4, and collected a total of ~25 hours of (brut) data. After "cutting" data collected during turns, climbs and descents, we are left with about 20 hours of data that have scientific value. A typical day of measurements consisted of two flights, one starting at 10 a.m. and the other starting at 1:30 p.m. Each lasted about 2.5 hours, including about 2.0 hrs at station and 0.5 hr of commuting to and back from the site. On two of the flight days (May 25 and June 4), the wind was from the North. On the four other days, the wind was from the South. All flights were performed at a targeted airspeed of 25 m/s, and were always within the range of 20-30 m/s. We now realize that some of the data collected at low airspeeds (20-22 m/s) might be slightly "tinted" by lateral erratic movements, which are difficult to avoid when flying crosswind at such low airspeeds with this type of light helicopter. We are in the process of finalizing a detrending algorithm that will either correct for such disturbances or eliminate the corresponding portion of the flight.

In addition to the flight legs illustrated in Figure 3, we sampled the boundary layer from bottom to top and from top to bottom at the beginning and the end of each flight. These climbing

and descending profiles were performed perpendicular to the other flight legs, into the wind, starting above the instrumented orchard.

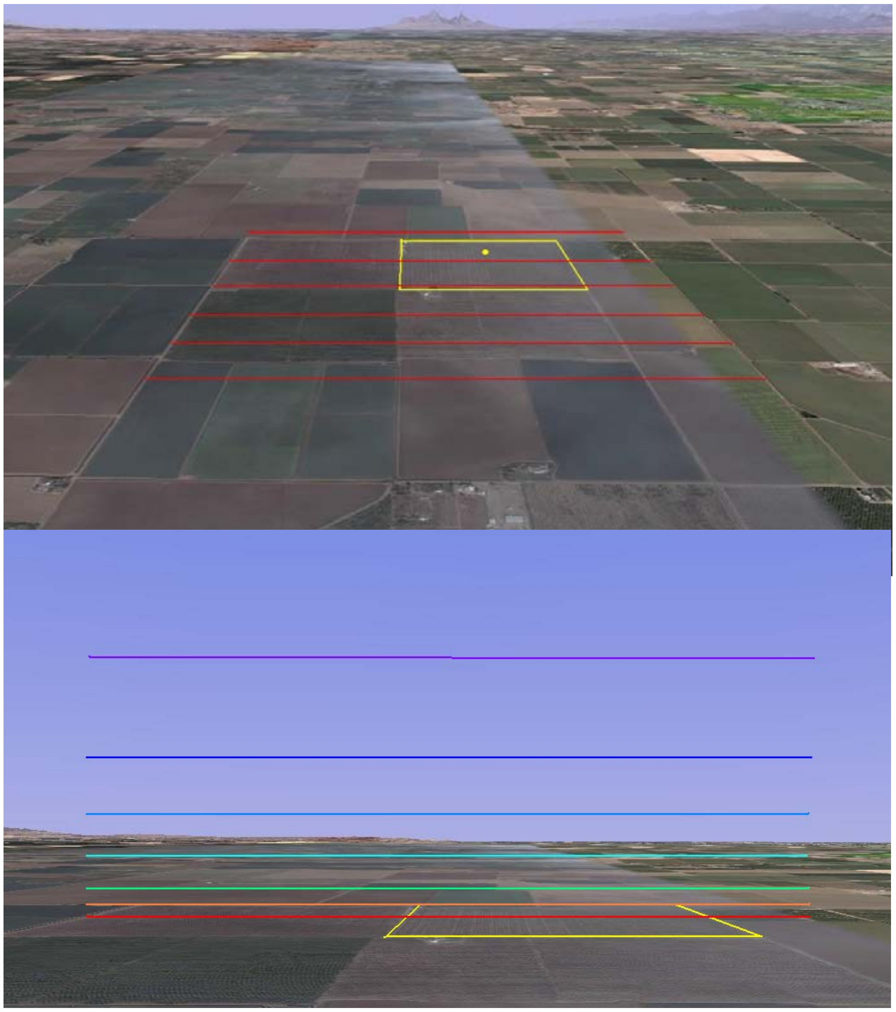

Figure 3: *Perspective views (oriented North) of the CHATS experiment site, which is highlighted in yellow. The yellow dot in the upper frame shows the location of the array of sonic anemometers. Red lines indicate the precise location of the six horizontal legs flown near tree top. The different colored lines in the lower frame indicate the different heights at which the six horizontal legs were flown, with the lowest one (red) being near tree top and the highest one being about 750 ft AGL. In addition to these flight legs, the boundary layer was profiled at the beginning and the end of each flight, which lasted about 2 hrs at station.*

Data Processing and Analysis

The data collected on board the HOP during this field campaign are being processed and analyzed. They are being used in three different studies. First, they help finalize the data processing algorithm that we have developed for the HOP. This algorithm is described in Holder and Avissar (2008). It involves denoising and detrending the data for various issues, including minor rotor effects, changes of altitude, erratic movements, frequency and airspeed of sampling, and flight leg length, among others. In addition, these data are being used to evaluate the performance of the HOP in measuring turbulence (Holder et al 2008). Indeed, the lowest flight legs were performed at about the same height as the sensors located on the tower that was erected in the orchard. Given the homogeneity of the orchard and the relatively large fetch available when the wind is from the South, we are comparing the turbulent fluxes measured on the tower with those measured on the HOP. Last, and more importantly, our data will be used with the data collected by the CHATS team to fulfill the overall objective of this project. As papers are submitted, they will be sent to ARO.

References / Publications Resulting from this Project

Avissar, R., H. E. Holder, P. Canning, K. Prince, N. Matayoshi, R. L. Walko, and K. M. Johnson, 2008. The Duke University Helicopter Observation Platform. *Bulletin of the American Meteorological Society* (submitted).

Holder, H.E. and R. Avissar, 2008. Measurements of turbulent fluxes in the atmospheric boundary layer with the Duke University Helicopter Observation Platform. *J. Atmos. Ocean. Tech.,* to be submitted by 04/01/2008.

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Summary of Personnel and Work Effort

The PI, Prof. Roni Avissar, directed all aspects of this project and conducted all flights. This project benefited from the participation of two graduate students and one undergraduate student (not funded by this project): Heidi E.Holder, Adam M Bolch, and Patrick Canning. As part of her Ph.D. research, Heidi worked on the calibration of the sensors currently mounted on the HOP and on the validation of the fluxes measured on-board the HOP with CHATS and other datasets. Adam started his Ph.D. in 2005. His work focuses on analyzing the data collected in CHATS and modeling it with the Ocean-Land-Atmosphere Model (OLAM), a new generation of Earth System Model developed in the PI's lab. Patrick simulates with Fluent (a state-of-the-art CFD) the HOP in flights. Both Heidi and Adam use the data collected during CHATS for their Ph.D. work.